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M. B. Ettinger, et al

Robert A. Taft Sanitary Engineering Center
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TABLE OF CONTENTS

WATER POLLUTION

	Page
Biology	1
Bacteriology	25
Chemistry	32
Oxygen Sag and Self-Purification	34
Surveys and Studies	36
Abatement and Control	41
Stream Standards	46
References	48

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WATER POLLUTION

Biology

Plant or other growths in domestic or industrial water supplies may create a variety of problems, many of which are intensified by pollution. Among these are tastes and odors, filter clogging, undesirable blooms, changes in water quality, and toxicity. Various methods and materials have been used for their control.

Tastes and Odors

Wells (262) emphasizes the importance of facilities to make possible treatment for tastes and odors due to microorganisms at any point in the water treatment process since each case is a separate problem. Matheson (160) also refers to the variety of treatments needed to combat tastes and odors and the need for selecting a treatment according to the cause and severity of each particular outbreak. Harlock and Dowlin (114) had success in elimination of odor due to algae by maintaining sufficient residual chlorine in the water. Fox (103) lists the factors in the environment which produce optimum conditions for taste and odor algae while Turre (246) had published photographs of a number of taste and odor organisms and mistakenly includes bacteria, fungi, and protozoa under the term, algae. Palmer and Walter (190) report plans for publication of colored illustrations of taste and odor, filter clogging, film-forming, and other algae of importance in water supplies, together with keys for their identification. A new handbook by Prescott (199) will also aid in the identification of algae.

Silvey (221) has continued his series of articles on actinomycetes in relation to water supplies with suggestions for their isolation and culture. Perlman (193) summarizes the physiological studies on actinomycetes. They are able to oxidize carbohydrates and lipids to CO_2. Most of them attack proteins and polypeptides and also are able to utilize nitrates and ammonia.

Algal Control

Reports on the control of algae and other organisms in the raw water supply indicate several variations in the use of copper sulfate. Derby and Graham (81) and Derby and Townsend (82) found that continuous addition of copper sulfate to maintain a concentration of 1.0 p.p.m. at the outlet of the reservoir was effective at Los Angeles, while Nesin and Derby (182) report control of Synura in New York with only 0.24 p.p.m. applied after the organism appeared. Czensny (74) observed that low concentrations of copper appeared to be more effective than large amounts and that evidence of excess copper could be obtained by comparison of the copper content of plants inside and outside of the treated area. Eidsness (89) states that a mixture of copper sulfate and citric acid was more stable in solution than copper sulfate alone and was much more effective.

Methods other than the use of copper sulfate for the control of algae are being reported by an increasing number of workers. Lawrence (143) reports the control of the branched alga, Pithophora, by dehydroabietylamine acetate (RADA), while McGowin, et al (163) state that RADA was unsatisfactory but sodium arsenite was satis-

factory for control of that alga.

Le Cosquino De Bussy (77) and Darragh and Stayner (75) have attempted, without full success, to check the growth of algae in swimming pools and industrial cooling systems with quaternary ammonium compounds. Jung (134), however, considers this treatment as the most modern method for swimming pools and bases its effectiveness on the removal of CO_2 from the water. Ronsonnet (203) and Matheson (159) describe the use of microstrainers for elimination of plankton while Stevenson (226) suggests the opening of scours to permit reservoirs to be washed clean at times of flood and the periodic emptying and refilling of reservoirs in order to reduce the likelihood of high plankton growths. Leibee and Smith (147) emphasize mechanical methods for removal of algae and the application of chemicals to create alkaline conditions in which phosphorous is precipitated and becomes unavailable as a nutrient for algae. Fitzgerald and Skoog (99) have continued their studies of 2,3-dichloronaphthoquinone (2,3-CNQ) as a selective algicide against bloom producing blue-green algae. Tests on a 27-acre lake have indicated that it was effective at 30-55 p.p.b. Repeated applications were necessary for continuous control.

Bartsch 27, Lund (157), Matheson (161), and Swartz (232-233) have summarized the practical methods now available for control of algae.

Control of Higher Aquatic Plants

Control of higher aquatic plants in reservoirs was considered by Steel and Ewing (225). Tests included borax, CMU, and 2,4-D.

Weeds, such as water milfoil, were controlled for a period of at least two years. The 2,4-D ester proved to be one of the most effective and was the least expensive.

Eggler (86) controlled water hyacinth with applications of 8 lb. per acre of 2,4-D but alligator weed was only slightly affected. Loiselle (155) reports continuation of experiments with chemical weed killers on a public water-supply watershed. Results with CMU showed that, within 6 - 7 weeks, no plants survived in the treated area and that growth was retarded for about two years. de Ong (80) has made a systematic survey of chemicals for the control of insects, fungi, and weeds which is useful for those whose responsibility for water quality requires them to be conscious of the possible hazards resulting from the wholesale use of such compounds as DDT, 2,4-D, lindane, chlordane, and others.

Pollutional Effects

A number of workers emphasize the changes in kinds and numbers of algae and other aquatic organisms brought about by pollution. Ryther (209) describes how pollution from duck farms favored the growth of the algae, Nannochloris and Stichococcus, over that of the more typical estuarine phytoplankton. Schulze(214) added $NaNO_3$ to a pond polluted by ducks and geese and which harbored growths of Euglena, Beggiota, Coleps, Euplotes, and Chromatium. Following addition of the nitrate, D.O. returned, H_2S odor and the organisms listed above, except Chromatium disappeared, and the green algae, Scenedesmus, Ankistrodesmus, and Actinastrum developed. Juneil (133) measured the effects of

factory wastes in several locations in a Swedish lake by determining the "chlorococcal-desmidal quotient." The presence of many species of chlorococcal (and blue-green) algae were considered to indicate high pollution while species of desmids (and armored flagellates) would be indicative of low or no pollution.

Kuhn (138) considered the changes in the net plankton population of Lake Zurich during a sixty-year period involving pollution by sewage and drainage from manured fields. Sudden mass developments of new plankton show that the lake is now unstable. The importance of utilizing all modern technical knowledge to reduce the addition of nutrient matter to the lake is emphasized. Sawyer (212) refers to the algal blooms and other nuisance conditions resulting from the fertilisation of lakes by sewage and other wastes and considers the many physical, chemical, and biological factors which influence these. Blum (39) reports on similar conditions in a Michigan river.

Flaigg and Reid (101) report that higher concentrations of nitrogen compounds, in a polluted stream, appear to accelerate the growth of algae so that they are concentrated in a shorter length of stream; and for this reason the high nitrogen concentrations may be more damaging than low concentrations. Beauchamp (28), in Africa, found unpolluted streams to be so low in sulfates that lakes into which they flow had only limited growths of phytoplankton. Gerloff and Skogg (108) found that the bloom producing alga, Microcystis, is capable of storing nitrogen and phosphorous nutrients in excess of its immediate needs and the amounts of these nutrients in the water, therefore, may be a poor indication of the amount of growth of which the alga is capable.

Blum (40) states that the pollution-tolerant diaton, Nitzschia palea, varies in numbers in a stream according to the time of day, the greatest number being found during the late morning and the minimum at night. Housden, v (120) summarizes the information on algae in water supplies in Holland. He also emphasizes the great need for research leading up to a standard method for quantitative determination of algae in water. Palmer and Maloney (189) describe a new microscope slide for counting nannoplankton organisms which are often disregarded in plankton counts. The slide permits the use of higher magnification with the microscope than is possible with the conventional Sedgwick-Rafter slide. Sverdrup (231) derives an equation which helps to predict the development of vernal blooms of phytoplankton in the sea, based upon certain hydrographic conditions. Lauff (142) found no correlation between phytoplankton count and water chemistry, while Verduin (249) showed that in western Lake Erie, the highest crops of phytoplankton arose in waters of intermediate, rather than in low or high turbidity.

Marine organisms are now receiving increased attention in relation to pollution. Cribb (71) reported heavy surf pollution of the South Queensland coast to be caused by the algae Colpomenia, Microdicton, and Enteromorpha. Beger (30) cites the migration of the water shrimp, Corophium curvispinum, from salt to fresh water and its distribution in German streams, lakes, and water works.

Toxic Algae

Reports from several sections of the country indicate that at certain times of the year dense algal growths have produced toxic materials which have killed domestic animals, birds, and fish. Ingram and Prescott (128) have summarized information on toxic algae and have illustrated forms which have been thought to produce a toxic material. These are all blue-green algae and include Microcystis, Aphanizomenon, Anabaena, Nodularia, Coelosphaerium, and Gloeotrichia. Shelubsky (215) reports that prolific blooms of blue-green algae occur in summer in fish ponds in Israel and heavy mortalities of fish result partly from oxygen depletion and partly from toxic substances. Shilo and Shilo (219) attribute fish mortality to the phytoflagellate, Prymnesium parvum, and suggest ammonium sulfate for its control. Alter (6) reports shellfish poisoning in Alaska is due to the flagellate, Gonyaulax catenella, which is used as their food. Grant and Hughes (110) suggest that the toxicity from algae might be associated with one particular stage in its development or decomposition. It appears that toxicity develops only gradually in blooms of the blue-green algae and decreases again as the algae decompose.

McLeod and Bondar (165) report animals died very shortly after drinking water from Lake Dauphin, Manitoba, which contained algal blooms of Aphanizomenon flos-aquae, Anabaena flos-aquae, and Microcystis aeruginosa.

Effects on Aquatic Life

Simmonds (222) reports that wood fibre discharged into

the Spanish River formed a sludge on the river bottom which was densely populated by worms but forms suitable as fish foods were scarce. Ferguson (96) found some fish kills in the Spanish River as far as 32 miles below the source of pollution. Worms were the dominant bottom form over a distance of 20 miles and fish from the stream had an objectionable flavor. Adams (1) describes an extensive fish kill on the Kalamazoo River in Michigan, where D.O. was absent for 40 miles downstream, B.O.D. ranged up to 50 p.p.m., and H_2S reached 2.5 p.p.m. Costin (70) reported a large kill of eels and sea mullet in Upper Lane Cove River, Sydney, Australia, in a brackish water area which receives industrial wastes rich in sulphur. Changes in the unsatisfactory environmental conditions in the lower Lippe during the period 1947 to 1950, are described by Bordo (43). The annual reports of the Severn River Board for the years 1951 to 1953 (216) indicate a marked deterioration in the quality of water in the upper Severn and severe pollution in the lower river, but some improvement was reported in the lower Tern and Frome. A reduction in the fishery values of the Rhine River due principally to industrial development and growth of towns is reported by Trahms (239).

A study was made of Alamitos Bay, a recreational area near Los Angeles, California (202). Conditions deleterious to aquatic life were found at one station where a sulfide odor was detected, and oysters had been killed. A study of bottom conditions in Los Angeles, Long Beach harbors which receive

sewage and industrial wastes (156) showed bottom fauna to be absent in some parts of the harbors. An ecological survey of the Castro Creek area in San Pablo Bay (97) which receives pollution from sewage and oil refinery wastes, showed a pH of 4.6 toxic chemical wastes, and no D.O. The bottom of the creek and estuary was devoid of animal life.

The results of a biological survey on the upper Moldau, Germany, which contains waste waters from paper factories, are reported by Nowak (185). The river is converted from an oligosaprobic stream, first to mesosaprobic and then to polysaprobic conditions below the discharge of the waste waters. A biological investigation in the estuary of the Avon and Heathcote Rivers, New Zealand, was made by Bruce (50). The rivers and estuary receive effluent from a sewage farm where sewage is settled and applied to land or treated in oxidation ponds. They also receive some trade waste waters, including the effluent from a starch factory. Progressive changes in the population of bottom organisms, as distances from the pollution sources increase, are given.

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Protozoan populations from two areas of Pymatuning Lake, Pennsylvania, are compared by Orr (188). The population of an area subjected to swamp drainage was similar to that of an area receiving sewage but more species were found in the sewage polluted area. Liebmann (151) reports on the first of a series of studies in Munich, under the title "Animal Parasites and Fish-Pathogenic Bacteria in Sewage and Fishing Waters." Lafon (141) found the fauna of the Rhone River at Lyons, France, to be characteristic of a rapid flowing, well-oxygenated water, low in organic matter. An

improvement in the method of disposal of pulp mill wastes in Washington, and the results of a pollution survey are described by Orlob and Eldridge (187). Fish kills which were observed in 1949 were not observed in 1951. Eldridge (90) cites the value of the water resources of the state of Washington as 292 millions and appeals for their protection for the economic welfare of all the people.

The pollution control agencies of the Pacific Northwest states are fighting to preserve the important salmon resources in the face of an expanding economy (91). A major problem is presented by toxic paper mill wastes. In Washington State (258) the following industrial wastes have been shown to be toxic to fish: pulping, plastic products, wood preserving, detergent, fungicide, plywood gluing, detergent solvents, bleaching, and metal finishing wastes. Large mortalities of the eggs and fry of chinook salmon in a hatchery were reported (126). Analyses indicated that the hatchery water contained 0.110 p.p.m. of zinc and 0.060 p.p.m. of cadmium which had leached from the galvanized hatchery trays. In 1953, Alabama biologists (119) made surveys of streams that had been poisoned by cotton insecticides in 1950. None of the streams had a great variety of aquatic invertebrates and none had desirable fish populations. Three of these streams had no game fish species at all.

Hemphill (116) using 0.1 p.p.m. of toxaphene killed all carp in a lake within 72 hours. Insect life was severely affected. Toxaphene breaks down in alkaline water and it was found that lakes with water of pH 8.0 and higher could be replanted with fishwithin

4 weeks. Bandt(23) discusses the effect of organic wastes on fish. The resulting oxygen depletion of the water often kills fish and the increase in sewage organisms adversely affects the fish food supply. The toxic effects of inorganic wastes containing metals, cyanides, and ammonia are mentioned. Substances that are known to affect the taste of fish are phenols, naphthenic acids, Kraft waste resins, higher aldehydes, and unsaturated hydrocarbons from synthetic rubber plants, and aromatic nitro compounds from ammunition factories.

Death of carp in water draining from sewage irrigated fields occurred when a high pH coincided with a high concentration of ammonium compounds in the water. The ammonium was the product of decomposition of protein in sewage and the high pH was caused by the mass development of phytoplankton (213). Eustis and Hillen (94) in studies of the effects of the Granby Dam on the Colorado River indicate that deposition and accumulation of sediment may cause a marked change in species of insects present. The Mersey River Board (170) reports on the survey data from several streams of the area. In the first and second annual reports of the Trent River Board (244- 243) information is given on pollution, pollution abatement, water resources, land drainage, fisheries of the region, and effluent standards. The use of domestic and industrial waste waters for agriculture purposes and the different requirements of agriculture and fisheries in the use of such waters and the value and risks involved, are discussed by Willer (267). Vivier (254) discusses research, waste treatment methods, and pollution legislation in England. An historical discussion of pollution abatement

efforts during the past 100 years in England is presented by Pentelow (192). The handbook of the Anglers Cooperative Association (10) discusses legislation relating to pollution of surface waters; its effects on riparian owners and precautions which they may take. Laws concerning the general conditions for discharge of industrial wastes; especially physical and chemical standards were put into effect in Belgium by royal decree (173).

Liebmann (150) reported on investigations into the practical use of the saprobic system in estimating pollution loads and effects. Stundl (229) stresses the importance of studying fish populations and the uses of biological methods for classifying sewage polluted streams. In England, the Ministry of Housing and Local Government (174) are discussing standard procedures and studying the practicability of using toxicity to fish as one of the tests for effluents discharged into streams.

The Schuylkill River in Pennsylvania (20) which was polluted very badly with coal washing wastes has recently been cleaned up and some areas have been stocked with fish. Neale and Eldridge (181) suggest that water quality may be seriously impaired by improper watershed protection. Lumbering, mining, gravel operations, improper grazing, and other agricultural practices, railroads, hydroelectric power development, and flood control projects may contribute damage. Measures are urged to overcome this damage by proper watershed management.

In general, fish in polluted water are heavily parasitized. Fischtal (98) suggests that the fish are weakened so they are more susceptible to attack and further, pollution may favor the develop-

ment of intermediate hosts and thus increase the certainty of the parasite finding the next host. Tarzwell and Gaufin (234) point out some of the possible effects of pollution on aquatic life and indicate environmental conditions which should be noted in stream surveys. Pertinent comments are made on the use and value of biological indicators of pollution and on the procedures for collecting and evaluating survey data. Communities of organisms typical of the zones in a polluted stream are described and plans for a mobile biological laboratory are presented by Liepolt (153). A series of publications by the Limnological Station of the lower Rhine (250) contrasts conditions in streams and lakes resulting from pollution, sets forth the part to be played by limnological research in national and international problems of water supply and the maintenance of satisfactory conditions, and deals with the distribution of zooplankton.

In a series of three papers Cooke (65) reports a new study of the fungi in polluted water. Gemmerich (107) summarizes the existing knowledge on nutrition and occurrence of sewage fungi with special reference to Leptomitus and Sphaerotilus. Slime forming bacteria and filamentous blue-green algae were found to be abundant in petroleum refinery waste systems (72). Bruce (50) describes changes in the fauna of the estuaries of two New Zealand rivers due to domestic and industrial wastes.

Dangers in the disposal of toxic wastes at sea are brought out by Hjorth (122) who reports that some war materials were taken in the nets of fishermen and that there were several outbreaks of

food poisoning from cod-roe contaminated by mustard gas from gas dumps in the Baltic.

Indicators of Pollution

Various types of aquatic organisms have been used as indicators of pollution. Brien (45) describes an apparatus for collecting diatoms from flowing streams and how they are used as indicators of the state of pollution in the stream. Wallace and Newman (256) in reporting on the condition of certain New Zealand beaches indicate that pollution depends on the effects of wind and tide. With normal wind conditions the diaton count has some value as an index of pollution.

Mohr (175) states that for both fresh and salt water, a knowledge of protozoan ecology permits a qualitative indication of pollution by domestic sewage and effluents from food-processing plants, but other invertebrates have proved more popular as indicators of trade waste waters containing toxic substances. Weimann (261) contends that macroscopically recognizable organisms are more easily examined and more valuable in examination of rivers than microscopic organisms. Thienemann (236) in a monograph on chironomids, discusses these organisms as nuisances in water supply reservoirs and distribution systems, as indicators of organic pollution, and as inhabitants of filter beds of sewage disposal plants. Lackey (139) feels that a study of microorganisms as indicators of particular types of wastes offers great possibilities.

The complete stabilization and clarification of raw sewage in an open channel, 8 to 20 ft. wide, and 4 to 24 in. deep, occurred

over a 6-mile course, with large white masses of protozoa being present in the zone of most active stabilization (195).

Effects of Water Quality

The changes in such water quality characteristics as temperature, dissolved oxygen, carbon dioxide and pH were studied both from the standpoint of tolerance by aquatic life and their effect on the toxicity of various polluting materials.

The upper lethal temperatures (50% of fish dead in 24 hrs.) for 14 species of fresh water fish are reported by Black (36). The temperatures varied from levels of 22 to 24° C for salmon fry and fingerlings to 35 - 36° C for carp and catfish. Degree of acclimatization to these temperatures had some effect. Brett (44) describes methods of testing for lethal temperatures and reports levels of 23.8° C to 25.1° C as the maximum for exposures of one week for young Pacific salmon. Sullivan and Fisher (230) made tests in which speckled trout (Salvelinus fontinalis) were free to move in water with varied temperatures of from 1° to 24° C and allowed to select their own level. The selected temperature rose in the early part of the winter. Hart (115) made a study, at different geographical locations, of variations in the lethal temperature and diagnostic morphological characteristics of 10 species of fresh water fish. With minor exceptions no evidence was found of a relation between lethal temperatures and morphological characteristics. Only 4 of the 10 species showed any appreciable difference with difference in geographical location.

The mean oxygen concentrations lethal to trout and bass at several different temperatures were determined (53). For brook

trout, the mean lethal concentration at 55° F was 1.59 p.p.m. and 2.54 p.p.m. at 70° F; for brown trout, 1.42 p.p.m. at 49° F and 2.53 p.p.m. at 69° F; for rainbow trout, 1.05 and 1.10 p.p.m. at 52° F and 1.82 p.p.m. at 71° F. For smallmouth bass, the mean lethal D.O. at 52.5° F was 0.63 p.p.m., and at 80° F, 1.08 to 1.15 p.p.m.

For most species of fish, the critical concentration of D.O. is higher in the summer than in the winter (201). The critical concentration of D.O. for six species of fish at various summer and winter temperatures are given. Duijn (86) discusses the importance of the concentrations of D.O. and CO_2 for the survival of fish. The minimal oxygen requirements and the amount of oxygen consumed per unit weight of fish at the various temperatures are given for salmonids, coarse and tropical fish.

The eggs of rainbow trout had a low oxygen requirement during the first stages of segmentation but the requirement increased rapidly with the beginning of gastrulation (83). In water low in D.O., the second stage gastrulation failed to take place.

In fish kept in sea water with a gradually decreasing D.O., no change in heart muscle glycogen occurred until the oxygen content fell below 3 cc/l (normal for sea water, 6 cc/l.). The glycogen content then decreased progressively as the oxygen decreased. At death from anoxia, the glycogen content had decreased to about 75 mg/100 gr (normal 1150 mg/100 gr) (67).

Byrd (57) found during periods of thermal stratification in farm ponds that the greatest numbers of fish occurred in shallow

waters and they were unable to live in water where D.O. was less than 0.3 p.p.m. and the CO_2 content was 4.4 p.p.m. or more. Bhaskaran (33) reports the possibility of a large scale mortality in fishes when organic manures are added to fish ponds, due primarily to the effect on the oxygen balance.

Alikunhi et al. (4) described a mortality of carp fry in water supersaturated with dissolved oxygen, while Costin (79) reported a fish kill caused by an oxygen depleting waste. Olivier et al. (186) reported that free cercariae of Schistosoma mansoni died rapidly when deprived of oxygen but that those in the snail can survive without oxygen. Fox and Sidney (102) showed that with decreasing concentrations of oxygen there was an increase in respiratory movements of caddis larvae.

Seasonal variations in the number of fish present in a channel carrying the effluent of a sewage works seem unrelated to the chemical changes in the effluent (259 and 5). Laboratory studies indicate that the precise level of oxygenation of a contaminated water is of great importance. In further studies with ammonia, it was found that the toxicity of solutions of ammonium salts depends on the concentration of unionized NH_4OH and NH_3. Survival of trout in a given concentration of undissociated NH_3 increased markedly with an increase of D.O.

Downing (85) found that the survival times of rainbow trout in concentrations of KCN in the range of 0.105 p.p.m. increased with the increase in D.O. between 10% and 100% of saturation. The effect was most marked in the lower concentrations of CN.

In an experimental study on the influence of CO_2 on the utilization of O_2 by some fresh water fish (35) it was found that the O_2 content was higher at death in tests where the CO_2 tension was increased. When CO_2 tension was low, the oxygen left in the water at the death of the fish was 4mm Hg for the brown bullhead, and 19 mm Hg for the brook trout. The CO_2 tensions causing death when a tension of 160 mm Hg of O_2 remained in the respired water ranged from 80 mm Hg for the blacknose shiner to 338 mm Hg for the brown bullhead.

The pH tolerance of the bluegill in buffer solutions and in a constant flow apparatus with a single acid or base was tested (242). The pH tolerance limits found in the constant flow apparatus were 4.0 in HCl and 10.35 in NaOH. Vivier (253) claims that pH less than 4.0 and greater than 9.5 can be lethal to the fauna of a stream. The injurious action is due either to the presence of dissociated H and OH ions or to a toxic action peculiar to the substance. Use of pH in field studies is often helpful in disclosing the nature and extent of pollution.

Waede (255)found that the flounder ismore resistant to changes in salt concentration and temperature than is the sole. There is no difference in their resistance to quinine and ethyl alcohol. Halsband (112) in an extensive study correlated the reactions and adaptations of fish to various external influences. He related respiration with temperature, pH, salt concentration and oxygen content of the external medium. He also studied the frequency of respiration in solutions of urethan, chloral hydrate,

quinone and after x-ray exposure.

Hiatt et al. (121) tried to correlate the chemical structure of 500 compounds with the degree and type of irritation they caused in fish. Nitro and nitroso compounds, certain halogenated organics, disulphides and quinones all irritated fish by inhibiting the sulfhydryl groups in the chemical sensory systems.

Guppies of both sexes kept in water containing initially 200 c/l of P^{32} for periods up to 150 days were rendered sterile (252).

Bioassays and Toxicity

Laboratory studies of the toxicity of many materials to aquatic life were reported.

Muhrmann et al. (270) briefly outlines procedures and methods to be followed when conducting bioassays with fish. They propose a six hour bioassay period and discuss the choice of fish, size of fish, acclimatization number of fish per test and manifestations of toxicity. Saila (211) investigated the effects of varying the volume of toxicant solution, aggregation, temperature and change in condition of the test animal upon results of bioassays. In spite of relatively favorable experimental conditions it seems that estimates of relative toxicity using fish are effected by uncontrolled variations which may limit the dependability of results.

Anderson (8) discusses the use of Daphnia magna for bioassay procedures and how changes in water quality may effect industrial and biological uses. Allan et al. (5) suggests the use of floating live boxes to confine fish at fixed points in an industrially pol-

luted stream. They indicate that the absence of fish in the effluent during the winter may not be due to adverse chemical conditions but that many migrate to other places and return in the spring.

Vernon (251) reviewed the literature on the toxicity of copper, lead, and zinc to fish. Among subjects discussed were the effects of heavy metals on fish, toxicity levels, and the effects of water chemistry on the toxicity of these metals. Trama (240) using bluegills as test fish found the 96 hr Tl_m for Cu was 0.74 mg Cu/l and the 48 hr Tl_m was 0.90 mg Cu/l. Toxicity is due to the Cu ion and is independent of the anion.

The decline in the salmon fishery in the Pacific Northwest is correlated with heavy sulfite waste liquor (SWL) production (258). The following mortality threshold for salmon in SWL at various ages were determined. For chinook salmon 38 days old, 1,175 p.p.m.; 280 days old, 600 p.p.m.; 305 days, 560 p.p.m.; for pink salmon 102 days old, 1550 p.p.m.; 198 days, 530 p.p.m.; silver salmon 351 days old, 1230 p.p.m.; 412 days, 1015 p.p.m. Marine food organisms are less tolerant to SWL than young salmon.

Rainbow trout were placed in 1/220 M solutions of ammonia, hydroxylamine, hydrazine and mono, di, and trimethyl amine and their activity was measured (69). Fish were most active for prolonged periods in the presence of hydroxylamine and least active in the presence of NH_4OH.

Acrylonitrile breaks down in water to yield HCN. The lower tolerance limit to fish is about 20 - 25 p.p.m. while 100 p.p.m.

will kill in about 24 hrs. Acrylonitrile is also toxic to crustacea and aquatic insect larvae (24).

Turnbull et al. (245) determined the Tl_m of bluegills to twenty C.P. chemicals and to 14 industrial products and petroleum refinery wastes.

Gas liquor containing 2600 p.p.m. phenol even when diluted 600 times was lethal to trout in 12 hours. Gammarus, Tubifex, and chironomids were not affected (152). The minimum lethal dose and the time of survival of five species of fish belonging to the sunfish family in seven preparations used in oil well drilling operations was determined by Anderson (7). Caustic soda, white lime, and oil well cement were most toxic.

LeClerc et al. (146) believed that fuel oil and lubricating oil caused the death of fish by preventing the reoxygenation of the water. Bioassays indicate that fuel oil has some toxicity.

The minimum lethal doses of some detergents and soaps in distilled and tap water are given and symptoms of poisoning are described (144). Soaps were more toxic in distilled water than in hard water. With most detergents the type of water has little effect on their toxicity. Minimum lethal concentrations of various detergents varied from 2 to 20 p.p.m. For the soaps, the minimum lethal concentrations ranged from 10 - 12 p.p.m. in soft water and from 250 - 1000 p.p.m. in hard water.

Sachs (210) found that fish and arthropods were more sensitive than bacteria to benzene and benzene hexachloride. In saturated solutions, protozoa and algae were killed almost instantly and fish

were injured in one to four minutes. Servoots (32) controlled black-fly larvae with a single dose of benzene hexachloride (3 p.p.m.). There was no change in the number and kinds of planktors in the stream after treatment. In laboratory tests, a toxic effect was observed only when the concentration exceeded 30 p.p.m.

When the water in the river Ploisso contained 20 p.p.m. phenol and 0.0 p.p.m. D.O. no life existed (25). When the D.O. increased to 5.3 p.p.m. and phenols decreased to 4.3 p.p.m. protozoa and algae appeared and increased in variety and quantity as the phenols were reduced to 0.2 p.p.m. In laboratory experiments, river protozoa tolerated phenols and cresol up to 300 p.p.m. pyrocatechol, 150 p.p.m., resorcinol, 600 p.p.m.; phloroglucinol, 650 p.p.m. pyrogallol, 33 p.p.m., and hydroquinone, 6 p.p.m. Increasing the temperature increased the toxicity.

Vallejo-Freire et al. (247) found that concentrations of quaternary ammonium compounds that kill cyprinodont fish within one hour will kill Australorbis snails within 24 hrs. Jakoski (130) found that the various synthetic detergents showed a varied molluscicidal activity against Stagnicola reflexa. No correlation between chemical structure of the detergent and toxicity could be shown. An anionic alkyl-arylsodium sulfonate was most toxic. The toxicity of 32 inorganic and organic mercury compounds to molluscs was determined (42). Thirteen organic mercurials at concentrations of 1 p.p.m. were 90 - 100% effective against Australorbis glabratus. At 0.3 p.p.m. isopropylmercuric thiocyanate and phenylmercuric acetate killed 90% of the snails.

Wilkinson (266) reports minimum lethal concentrations of sulfides as sodium sulfide at 3.0 p.p.m., mercaptan at 0.5 p.p.m. as methyl mercaptan, resin acid fraction of soap (Na salt) at 5 p.p.m.

In experiments to control molluscs, Wright and Dobrovolny (269) report on the efficiency of 33 compounds. In stagnant water the most effective molluscicides were pentabromophenol, pentachlorophenol, sodium and copper pentachlorophenates, bis (3,5,6-trichloro-2-hydroxyphenyl) methane and its sodium salt and phenyl mercuric acetate. These compounds in a concentration of 10 p.p.m. killed 99 - 100% of snails, and most were effective in a concentration of 2 p.p.m.

D.D.T. and Hexa were confirmed to be strong fish poisons (180), and in aquaria the quantity normally used for fly control is absolutely lethal to aquarium fishes.

Werner (263) reports treatment with thiouracil to have some effect on German brown trout eggs and fry.

McGraw (162) reports that the bacterium causing furunculosis of fish survives longer in polluted water and that the degree of infection increases with the quantity of pollution.

Fjeringstand (100) found that Daphnia magna could not survive in sewage in which ammonia was demonstrable.

Nietzke (184) investigated the effect on fish of hormone weed killers. Di and tri chlorophenoxyacetic acid differed in their action on fish with the greatest damage caused by mixtures of the two. Emulsifying agents harmed fishes by attacking the mucous membranes and gills.

The addition of CO_2 to a lethal ammonia solution markedly reduced the toxicity of the solution to rainbow trout. The CO_2 decreased the pH of the solution and increased the ionization of the NH_4OH (3). The toxicity of the chloride, sulfate and nitrate salts of Na, K, and Ca to the bluegill was determined (241). The relative toxicity of the cations was Na < Ca, < K. The relative toxicity of the anions based on experiments with the sodium salts, was Cl < NO_3 < SO_4.

In the first addendum to "Water Quality Criteria" (164) McKee briefly reviews some recent publications on the toxicity of pure substances and industrial wastes to fishes and other aquatic life. These works are especially valuable for the arrangement of references according to subjects and the complete bibliography.

Bacteriology

Only 11 outbreaks of disease were reported (76) in 1953 for which epidemiological investigation or laboratory test indicated that water was the vehicle of infection. In one outbreak, two cases of typhoid fever in the same family were attributed to swimming in a river. Two outbreaks of infectious hepatitis were associated with cross connections of water supply and sewage disposal. No outbreak was reported in which a city water distribution system was at fault.

Sewage disposal, water supply and gulls have been implicated in the spread of Salmonella to humans in Ketchikan, Alaska (11). Gulls became contaminated while scavenging along shore-line areas where outfall sewers discharge, and later polluted the community's surface water supply. Cultures of organisms from gulls and from two hospitalized patients with gastroenteritis were identified as the same species. Broek et al. (48) has reported the contamination of polder water (Netherlands) with S. paratyphi owing to the influx of sewage, although neither the origin nor the reason for the contamination was discovered. A water-borne epidemic of S. paratyphi infection (25) occurred in a small town in Slovakia where many inhabitants obtained water from a stream. Thiele and Brinkmann (235) presented the results of a study to determine the most suitable method of detecting S. typhi in water and to develop a reliable procedure also suitable for the bacteriological examination of sewage and polluted surface waters. Best results were

obtained with Lovrecovich's modification of Wilson and Blair's bismuth sulphite medium which strongly inhibited accompanying bacteria but permitted easy recognition of S. typhi and certain other Salmonellae.

Jensen (131) examined the sewage from five towns with tuberculosis sanatoria and from one institution for the care of feebleminded which had a tuberculosis ward. These six effluents were treated in biological-purification plants. Tubercle bacilli were demonstrated in the influent to all the plants and in the digested sludge of all those receiving sewage from areas having a ratio of one infected person to 600 or less uninfected people. From eleven and one-half to fifteen months were required before tubercle bacilli could no longer be demonstrated in the sludge kept on the drying beds. The addition of 10 mg. of chlorine per liter of effluent from an activated sludge plant was found effective in destroying tubercle bacilli.

An explosive exacerbation of a poliomyelitis epidemic in Edmonton was described by Little (154). The series of events associated with the epidemic provided circumstantial evidence and epidemiologically suggested that the outbreak of poliomyelitis was water-borne.

Melnick and his associates (168-169) have found that the gauze pad method yielded a significantly higher percentage of positive tests for Coxsackie viruses from sewage than the grab sample method. Of 1,929 samples of urban sewage examined from six states, 269 samples yielded Coxsackie viruses. In almost

every urban area studied, viruses appeared in some of the specimens collected in the summer and fall, and disappeared during the winter and spring.

In an investigation to determine the efficiency of primary sewage treatment plus chlorination on the removal of animal parasites, Wang and Dunlop (257) found that approximately 20 per cent of the Ascaris ova and 46 per cent of the Endamoeba coli cysts in the raw sewage were still present after treatment. Cysts of Endamoeba histolytica were not found in either raw or treated sewage. The MPN of coliform organisms and enterococci showed a decrease of more than 99 per cent during the same treatment.

Cooke (65) has reviewed the literature on fungi in polluted water and sewage. In a comparative study of media for the enumeration and isolation of fungi, he found that an altered Martin's modification of Waksman's soil mold plate count agar to be the most efficient. Of 105 mold species isolated from a polluted stream, only six were present in all samples examined and only 48 were found in four or more of the eight stations studied. Surface stones from three positions on a trickling filter were examined by Hesseltine (118) at monthly intervals during the period of a year. The filters received miscellaneous chemical wastes and large amounts of antibiotic production wastes. Three species of fungi were found at all times and were considered the only species regularly inhabiting the filters. Other species observed were considered chance contaminants.

Morris and Weaver (178) determined the coliform and streptococci MPN for duplicate samples of well water. One sample was examined immediately after collection and the other after 24 hours storage at room temperature. Coliforms and streptococci were deemed to be of equal value as index organisms for detecting the presence or absence of pollution. In their opinion the tests for streptococci required less time and materials than the tests for coliforms. Gilcreas and Kelly (109) investigated the significance of the coliform test in relation to intestinal virus pollution in water. They studied the survival of coliform organisms in water and sewage in comparison to E. coli bacteriophage, Coxsackie virus, and Theiler virus when subjected to heat, chlorine and ultraviolet light. They concluded that, except for storage in the cold and weak chlorine doses, water treatment which destroys coliform bacteria can be counted on to destroy viruses as well. In his recent review paper, Stuart (228) has stated that bacteriological examinations do not provide an absolute answer to suitability of water for human consumption, but must be supplemented by sanitary survey. The Engineering Section of the Missouri Basin Health Council (215) has adopted criteria to guide the pollution control programs in the basin.

In a laboratory study of the efficiency of water treatment processes, Metzler et al. (171) showed that settling of either natural turbidity in a water or a floc produced by coagulation with alum concentrated a majority of the H. capsulatum spores in the sediment, and that model rapid sand filters did not effect complete

removal of either the yeast or the mycelial phase of H. capsulatum suspended in water. Experimental results indicated minimal effective contact times of four hours with 0.35 p.p.m. free chlorine and 35 minutes with 1.8 p.p.m. free chlorine. Ritter (205) and Cooke and Kabler (64) have reported survival of H. capsulatum in excess of 100 days in sterilized tap water and Ohio River water at 4°C and 20°C.

At summer temperatures, few E. coli will survive more than eight hours in Great Salt Lake water, but at 6°C approximately 50 per cent will survive 24 hours exposure, Fraser and Argall (104). Angelillo (9), using mineral (alkaline bicarbonate type) waters of Sardenia, found that E. coli survived as long as 28 days at room temperature. In experiments by Buttiaux and Lewis (56) approximately 50 per cent of S. typhi, S. paratyphi B, and S. enteritidis survived 44 hours in North Sea water at 18°C.

Regarding the disinfection of water, Hofmann and Enhuber(123) concluded that Katadyn silver could be used even in grossly impure waters, but that a concentration of up to 50 ppb silver must be maintained for from three to nine hours. Cortelyou et al. (68) presented data to show the germicidal efficiency across a wide range of ultraviolet light intensities. The apparatus used effectively freed waters of E. coli when present in concentrations exceeding 1,000,000 per 100 ml and the U-V intensity was at least 630 MW per sq. ft. Ozone free of hydrogen peroxide and nitrous oxide used by Dickerman et al. (84) was effective in killing bacterial suspensions containing little organic matter. In raw waters, concentrations of

ozone up to 2 p.p.m. for at least five minutes exposure were required because organic matter appeared to inactivate some of the ozone. Bringmann (46-47) compared the action of ozone and free chlorine in drinking water and reported that ozone destroyed bacteria of the coli group much faster with a relatively smaller amount of gas and in a shorter time. Depending on conditions of temperature, hydrogen ion concentration and chlorine content, Clark and Kabler (61) found that from 7 to 46 times as much free chlorine was required to inactivate a purified suspension of Coxsackie virus in water as was necessary to kill a suspension of E. coli cells. Morris et al. (177) have described the composition of water soluble tablets for disinfection of drinking water under field conditions. Such tablets will dissolve in less than one minute at room temperature, liberating 8 mg. of elemental iodine per tablet and will satisfactorily treat one liter of most natural waters within 10 minutes.

Levin and Laubusch (148) used a membrane filter procedure for the control of an emergency water supply. They examined the water from 299 Pullman cars by Standard Methods fermentation tube test and a membrane filter technique, and obtained comparable results. In a report of a field study of the Standard Methods Committee for the Examination of Water and Sewage, Kabler (135) compared the results of 1,706 water samples examined simultaneously by the membrane filter and Standard Methods MPN procedures. The results of the two methods were compared on the basis of the 95 per-cent confidence limits of the confirmed MPN. On this basis, results of 73.8 per cent were in agreement. Of 650 samples having a coliform

content in the range associated with potable waters, 88 per cent showed results in agreement by the two tests. Jeter et al. (132) studied type differentiation of coliform organisms with the membrane filter technique. They found that from 92 to 95 per cent of coliform organisms growing on the membrane filter develop a characteristic "metallic" yellowish surface luster and subsurface color, and that the great majority (95 per cent) of colonies that do not develop sheen and color are not coliform organisms as defined by Standard Methods. Hajna and Damon (111) have described a new membrane filter procedure for the detection of coliform organisms in water by a single-step technique. Broscheit and Zimmermann (49) compared the results of tests on 600 samples of water of varying quality and found no reason to recommend the substitution of membrane filter for the titration method. In a comparative study of the membrane filter with the Most Probable Number method of enumerating coliform organisms in water, Shipe and Cameron (220) found a significant difference in the recovery of organisms by the two procedures, the recovery by the MF technique being low. This difference was explained by the accumulation of toxic substances (copper and zinc) on the filters. In a comparison of the membrane filter and Most Probable Number techniques in examining sea water, Presnell, Arcisz and Kelly (200) concluded that the membrane filter method was a reliable technique for determining the coliform densities of sea water if due regard was given to water turbidities and bacterial densities in determining the volume of sample for filtration.

Chemistry

The effect of pollution by synthetic detergents has been considered from many angles. Degens, van der Zee and Konner (79) studied the effects of certain synthetic detergents on sedimentation. Consideration of the total problem was presented by an AWWA task group headed by Haney et al. (113). The Surveyor (18) commented on the first report of the committee on synthetic detergents set up by the Minister of Housing and Local Government. The committee "saw serious possibilities in relation to the efficiency of sewage treatment, the condition of rivers, and the purity of water supplies." Holroyd and Parker (125) investigated the effects of synthetic detergents on the dynamics of aeration. Bogan and Sawyer (41) made a notable study of "Biochemical Degradation of Synthetic Detergents." It was concluded that all principal anionic and non-ionic syndets are susceptible to some degree of biochemical degradation, that there was considerable variation in the rate of attack, and that the particular syndet type does not have bearing on the rate of attack, with biochemical degradation being a function of the molecular structure, influenced by small changes in the molecular arrangement.

The biological metabolism of phenol has been considered by two authors. In studies by McRae (166) the most prominent organism was found to be Achromobacter Cruciviae. Meissner (167) studied the organisms responsible for metabolism and the intermediate metabolites of a number of phenols.

The interrelationship of microorganism and sulfur compounds is the subject of two papers of interest. Bryner, Beck, Davis, and Wilson (52) concluded that most of the soluble copper and iron

found in acid mine drainage from Bingham Canyon are the products of biological oxidation of sulfide minerals. Their work, incidentally, was directed at developing methods for the profitable leaching of low grade ores. Wheatland (264) considered the sulfur balance in a polluted estuary. Sulfates are reduced to sulfides biochemically in the absence of oxygen. The temperature dependence of the biochemical reaction is delineated. The formation of sulfate from sulfide is reported to be a chemical oxidation in the Thames estuary. The presence of iron and suspended matter catalyzes the reaction, which may be limited by the availability of oxygen. Flaigg and Reid (101) considered the effect of nitrogen compounds on stream growths.

Studies of the concentration and chemical characteristics of the pollutants in refinery effluents led Ruchhoft, Middleton, Braus, and Rosen (208) to conclude that the most important source of taste and odor producing material was neutral organic material, consisting mainly of aliphatic and aromatic hydrocarbons and cyclic sulfur compounds. It was estimated the refinery effluents would cause taste and odor problems at water plants if they entered raw water in concentrations in excess of 1-1000. Hueper and Ruchhoft (127) studied chemicals recovered from raw and finished waters for the presence of possible carcinogens using bioassay techniques. Chemicals recovered from a raw water polluted with refinery effluents "were weakly positive when painted on the skin of mice."

Oxygen Sag and Self Purification

Camp (58) commended a method for estimating stream self-purification capacity proposed by Churchill (60). Black and McDermott (37) discussed various factors affecting oxygen sag. Mueller (179) also considered factors related to oxygen sag and presented illustrative calculations.

Wiegand (265) presented a procedure for determining the constants of the well known monomolecular B.O.D. formulation. The procedure suggested appears to be closely related to the "Thomas Slope Method."

The resistance of individual materials to self-purification has been considered in several papers. Ettinger, Lishka, and Kroner (92) investigated the persistence of pyridine bases in polluted waters and found these materials to be subject to complete biochemical destruction in short periods under favorable conditions. Ettinger, Lishka, and Moore (93) reported furfural subject to very rapid biochemical destruction with the material also subject to vaporization loss and chemical oxidation. Kroner and Moore (137) reported lignin to be highly resistant to attack in polluted water with very slow degraduation of the chemical reported under all conditions investigated. Mills and Stack (172) studied the biological oxidation of relatively concentrated solutions of a large number of chemicals. They reported four groups of materials: (1) Synthetic chemicals readily oxidized biologically, (2) Synthetic chemicals oxidized after an initial lag, (3) Chemicals oxidized at very slow

rates, with or without initial lag, and (4) Materials which resisted biochemical oxidation for extended periods under their study conditions.

Surveys and Studies

Several articles published this year concerned pollution of tidal rivers, estuaries, beaches, harbors, and lakes. Factors to consider in obtaining data necessary to estimate the waste assimilation potential of a tidal river were discussed by Laffey (140). Pollution of a sheltered harbor on Long Island by cabin cruiser waste discharges was reported by Ingram and Diachishon (129). Health hazards to persons swimming in adjacent waters, as well as coliform densities exceeding those approved for shellfish waters, were found to exist. Moore (176) surveyed beach pollution at a seaside resort before and after installation of a new sewer outfall. The presumptive coliform count on samples of sea water was found to be a satisfactory index of contamination and the conclusion was reached that a large series of tests by a relatively simple technique is preferable to a more limited investigation by more complex methods. Bacteriological standards for bathing beaches are discussed. Orlob and Eldridge (187) describe the use of an under water disposal line to disperse pulp mill wastes in a bay to prevent an oxygen deficient water barrier.

Stratification and overturn in English lakes and reservoirs and related water supply problems were discussed by Thompson (237). Cooley and Harris (66) wrote of the use of inflow jets to prevent stratification in reservoirs. Factors involved in disposing sewage effluents to lakes were discussed by Sawyer (212) particularly with

regard to causing "biological explosions." Rice et al. (204) considered the general character of wind generated waves and their possible effects on the mixing of wastes discharged to large bodies of water. He concluded that waves produced by wind cause appreciable mixing and that wind blowing over a sewage field will cause a surface layer of the field to be translated at an appreciable rate in the direction of the wind.

A new automatic current float for studying rate and direction of movement in large bodies of water is described by Carruthers (59). This deep-riding buoy after floating freely for a time away from a chosen liberation point anchors itself, hoists a flag indicating it has done so, and registers the time at which its travel ceased. Construction details and drawings are given.

Several articles dealing with the condition of streams or effect of pollution on streams were published in 1953. Materials which could occur in a well purified sewage effluent and yet might have adverse biological influence on a stream if little dilution were available are considered by Roberts (207). One of the conclusions reached is that the residues of detergents present in an effluent of an efficient sewage treatment process have not been modified in such a way to remove their toxicity.

Wuhrmann investigated the variations in the types and abundance of microscopic organisms on the bed of an artificial channel when receiving various dilutions of raw and treated sewage (271). The investigation showed that dilution of settled sewage to such a degree that detrimental effects on the oxygen balance

of shallow, turbulent streams are excluded may still induce quite undesirable growths of heterotrophic river bed organisms (for instance, SPHAEROTILUS). The tests showed good correlation between river biocoenosis (river bed organisms) and the concentration of polluting matter in water measured by B.O.D., oxygen consumed from K Mn O_4, and organic nitrogen. Equal concentrations of B.O.D., etc. in settled and treated sewage did not produce comparable associations of organisms however. Curves are presented relating the biocoenoses of a stream and the B.O.D., oxygen consumed, and total N using settled sewage, low rate activated sludge effluent, and high rate activated sludge effluent. A chart also shows the dilution necessary to avoid heterotrophic organisms on the stream bed for sewage receiving various treatments.

Pillai et al (195) describe the natural purification of sewage in an open channel in India in 4.75 mile of flow. At the point of most active stabilization large white masses of protozoa were found.

Stoessel (227) writes of contamination of streams by oil in Germany and lists possible waste sources. Detergents as pollutants in Kansas stream are the subject of a paper by Culp and Stoltenberg (73). An anonymous article (22) describes trouble in a water supply at Wheeling, West Virginia, purportedly from detergents. Hohle (124) describes the effect various pollutants have on the preparation of boiler feed water. Chlorides shorten the life of demineralizers. Organic pollution causes viscous deposits on the beds, and when high the distilled water contains CO_2 and NH_3 .

Organic pollution has effect on removing oxygen in degasifiers.

The underground movement of bacterial and chemical pollutants in ground water was the subject of an investigation by Butler et al. (55). The study showed that bacteria in fine soils may not move more than five feet but in coarser soils travel will be further. In ground water, coliforms have been reputed to move 10 to 232 feet. Chemical pollutants move further and faster and may move several miles. Lieber and Welsch (149) report an instance of cadmium contamination of ground water in Long Island from plating wastes. No standards exist for cadmium in drinking water and no standard methods for the chemical analyses exist. Up to 3.2 p.p.m. were found.

A final report on field investigation and research on waste water reclamation and utilization in relation to underground water pollution was released (224). This study determined that a high degree of sewage treatment is necessary if the effluent is to be spread efficiently. Suggestions for the "conditioning" of the soil, both initially and at six-month intervals thereafter, are made. The study offers evidence that the practice of spreading can be bacteriologically safe. The report also cautions that two other nuisances besides pollution must be guarded against: the spreading pond can be responsible for mosquitoes and possible algal odors.

An English report (12) on use of wastes for agriculture states that of the approximately 1,000,000 tons per year of dry solids contained in English and Welsh sewage 350,000 tons are used for fertilizer.

The quality of surface waters east of the Mississippi is the subject of one report (95). It includes a bibliography of published and unpublished analyses of the surface waters. The polluted condition of the Holston River in Tennessee was reported as preventing new industries from being attracted to the area (14).

A rapid method for estimating stream pollution caused by spent sulphite liquors is proposed by Kleinert and Mincer (136). This method involves the determination of lignosulfonic acid by the lyeosine technique and use of the potassium dichromate oxygen consumed test.

Cleary (62) discusses a project underway to make a comprehensive literature survey of toxicity in the water supply and sanitation field. The information is being prepared on punch cards for easy reference.

The Report of the Water Pollution Research Board for 1952 (19) summarizes research in England carried out in 1952 on the following subjects: water, sewage, industrial waste waters, and toxicity.

Abatement and Control

The effects of river developments for water supply, hydroelectric power, navigation and flood control purposes on stream self-purification capacity have been discussed by Velz (248). Poor location and/or operation of such facilities can result in greatly reduced waste-absorbing capacity of the stream. Velz has emphasized the desirability of multiple purpose developments, one important purpose being low flow regulation to increase the capacity of the stream to handle deoxygenating wastes. Ahlgren et al. (2) have reported trends of current thought regarding multiple use of watersheds and water supplies. Views of water supply engineers, recreation departments and consumers are reported.

Cohn (63) has reported the recent appropriation of two million dollars by the Pennsylvania Legislature for partial repayment to municipalities of the costs of pollution abatement measures. A progress report on pollution abatement in Indiana has been made by Poole and Holtje (198) who indicate improvement of 1,000 miles of Indiana streams as against 500 miles still considered polluted. The Indiana program has been, briefly, to prevent new sources of significant pollution, to locate and eliminate existing major sources and to make reasonable and economic use of the natural self-purification capacity of streams insofar as feasible. Frost (105) has described the production and utilization of movies on water pollution in New Hampshire.

A report on the Missouri River Basin Compact has been given by Schwob and Hopkins (215). Ten states are involved. Desirable

stream criteria, and the present inadequacies of waste treatment facilities are discussed.

Dechant (75) has described the effectiveness of the reclamation program for the Schuylkill River in Pennsylvania. As a result of dredging and enforcement of the State Anti-pollution Law the once-foul river has been vastly improved and is now available for recreational uses (20). Sewage treatment at Roanoke, Virginia, has resulted in marked improvement of the Roanoke River (106). The California Central Valley Regional Control Board has adopted a strict anti-pollution policy for the Sacramento River (16). The minimum dissolved oxygen requirement for the entire length of the River is 85 per cent of saturation.

Dworsky (87) has indicated that one of the basic factors controlling the development and location of new industry will be the availability of water, with respect to both quantity and quality. Industry's water needs have increased greatly in recent years and can be expected to continue to grow, while the natural supply of water is relatively constant. It is therefore the responsibility of industry to practice conservation, pollution abatement and reuse in order to make better use of the available supply. The need for integration of all water operations and uses for most efficient use of the nation's water resources has been stressed by Watson (260). There is lack of agreement regarding stream standards and acceptable pollution loading, leading to confusion and inefficient utilization of available water. Watson has also called for equipment for automatic, continuous recording of

water quality and for more adequate training in pollution abatement.

Pirnie (196) has stressed the necessity of eliminating in advance industrial wastes which, if discharged to a stream, might affect human health. He has discussed a number of wastes in terms of their effects on safety and palatability of drinking water, recreational uses of the stream and quality of water available to downstream industrial users. The suggestion that industries pool their money to combat pollution has been made by Stanley (223) and Berry (31) has indicated a need for better operation of waste treatment facilities.

Efforts of Warner Gear Division to eliminate discharge of cyanide wastes have been described by Barr (26). Under cease and desist order of the State of Indiana, cyanide wastes were eliminated by a process change, but this created an oil wastes problem. The latter was solved by the use of separators and an infiltration lagoon. Cooperation of the company and the Indiana Stream Pollution Control Board has thus resulted in a very satisfactory stream condition. Poole, Holtje and Belter (197) have proposed a simple curb to surround tanks holding cyanide solutions in order to collect accidental spills of cyanide and prevent their discharge to the stream. Wastes from the American Cyanamid Company are being studied in a pilot installation to determine design factors for the Somerset-Raritan Valley Sewerage Authority in New Jersey(15).

Operation of a half-million dollar waste treatment plant by the Koppers Company has been started at Follansbee, West Virginia (21). This installation was preceded by six years of research, and the process is designed to accomplish better than 99 per cent

removal of phenolic wastes. Masselli and Burford (158) have reported on characteristics of wastes produced in a cotton finishing mill and the possibilities of chemical treatment. Sulfite waste discharges to the Wisconsin River will be reduced to less than 25 per cent of their former level as the result of a large waste treatment program to be undertaken by the Nekoosa-Edwards Paper Company (13).

The dangers inherent in reclaiming sewage and industrial wastes have been discussed by Bush and Mulford (54), who indicate that there are some 200 locations in California where waste waters are utilized. Pickett (194) has discussed the problem of pollution of ground waters, and has urged that it be stopped. Brune (51) has indicated that high sediment concentrations represent one of the important forms of stream pollution, and has discussed this problem in terms of types and extent of damage, sources of harmful sediment and remedial measures.

A discussion of legal problems and decisions with respect to water rights and uses in Michigan has been presented by Billings and Booth (34), who note that the Michigan law is contained in decisions of the State Supreme Court, rather than in acts of the legislature. Recent higher court decisions on wastes cases in several states have been reported and discussed by Parker (191). The cases included questions as to (a) special assessments upon property located outside of a lawfully created sewage district, (b) the sewage district as a separate tax entity regardless of whether its geographical limits coincide with those of a city, and

(c) liability of individuals for removal of materials from the bed of a navigable stream. The Connecticut Supreme Court of Errors has upheld a decision of a Connecticut trial court extending the time within which a defendant (the City of Norwich) was required to comply with an order issued by the State Water Commission (17). It was held that the change in dates did not make a material change in the order of the Commission.

Stream Standards

The recent literature considers some of the major factors which affect the choice of stream standards in specific situations, and indicates the unsuitability of rigid standards designed for general application to all streams and locales within a large area. Participants at the 1953 Industrial Wastes Forum (38) were generally agreed that standards should be selected on the basis of most beneficial stream use. It was indicated that waste disposal is one of the legitimate uses of a stream, and it was generally agreed that the natural self-purification capacity of a stream is an economic asset which should not be wasted. The discussion also indicated the need for separate, thorough study of the factors involved in each individual situation, since no two cases are identical. Kittrell proposed classification of individual stream stretches rather than entire streams, on the basis of most beneficial use, a device which has been successfully applied in the past and which has considerable merit.

Hess (117) and Leclerc and Beckmans (145) have emphasized again the need for consideration of the natural self-purification capacity of a stream as a factor to be weighed in setting standards. In reviewing the British Rivers Act of 1951, Roberts (206) has indicated a need for modification of its general B.O.D. effluent standard so as to allow for the high reaeration capacities of shallow streams and the dissolved oxygen content of sewage effluents. Towne (238) has reviewed the development of water quality criteria,

and emphasized the growing demand for water which can be reused. Viewed in this light, he has indicated the need for stream standards which are sufficiently flexible to accommodate future changes in social and economic conditions.

Sharpe (217) has noted the water quality criteria adopted by the International Joint Commission on Pollution of Boundary Waters and recommended by the Pollution Control Board of Ontario for lake and river waters used as sources of domestic water supply. He indicates that these criteria would generally require waste discharge quality of (a) 20 parts per billion phenol equivalents or less, 17 parts per million iron or less and 15 parts per million or less of oils as determined by extraction; (b) pH between 5.5 and 10.6; (c) treatment for removal of bacteria, odor-producing, toxic and deoxygenating substances. It is also noted that better waste discharge quality might be necessary in some cases. Nesmeyanova (183) has reported the following odor threshold limits for various phenols and their respective chlorophenols:

	Phenol	Chlorphenol
PhOH	25 mg./L.	0.001 - 0.0005 mg./L
Cresol	0.0025	0.001 - 0.0002
Thymol	0.05	0.05
Resorcinol	40	No odor noted
Hydroquinone	No odor noted	No odor noted
Creosote	0.125	0.01
Naphthol	7	0.5

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